AD-A049 776 RAYTHEON CO WAYLAND MASS F/G 17/9
UNATTENDED/MINIMALLY ATTENDED RADAR STUDY. VOLUME I. SUMMARY.(U)
DEC 77 A W GRENCH, J L BERUBE F30602-76-C-0389
UNCLASSIFIED ER77-4109-VOL-1 RADC-TR-77-401-VOL-1 NL

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER RADC-TR-77-401, Vol 1 (of two)	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) UNATTENDED/MINIMALLY ATTENDED RADAR STUDY. ~~Technical Report Summary~~ Volume I. Summary.		5. TYPE OF REPORT & PERIOD COVERED Final Technical Report
		6. PERFORMING ORG. REPORT NUMBER ER-77-4109-VOL-1
7. AUTHOR(s) A.W. Grench, J.L. Berube		8. CONTRACT OR GRANT NUMBER(s) F30602-76-C-0389
9. PERFORMING ORGANIZATION NAME AND ADDRESS Raytheon Company, Wayland MA 01778		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS P.E. 63101F, J.O. E2330103
11. CONTROLLING OFFICE NAME AND ADDRESS Rome Air Development Center (OCDE), Griffiss AFB NY 13441		12. REPORT DATE December 1977
		13. NUMBER OF PAGES 28
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Same 30p.		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Same

18. SUPPLEMENTARY NOTES

RADC Project Engineer: Adrian S. Briggs (OCDE)

This effort was sponsored by ESD/SR, Hanscom AFB MA 01731

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Radar
Unattended Radar
DEW

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The technical summary is a synopsis of the Unattended/Minimally Attended Radar Study to investigate the exploratory and advance development activities necessary to support the development of unattended and minimally attended radars. The study looked at several radar designs. The primary considerations were high reliability and low-life cycle cost, with the additional constraint that the unattended radars were to use no more than approximately 500 W of prime power. The conclusion of the study is that the technology is potentially available to next page

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build radars with MTBF's, an order of magnitude greater than that exhibited by present radar systems.

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SECTION 1

INTRODUCTION

This report summarizes the results of a study into the technical demands and related cost impacts of a new generation of radar systems capable of extended periods of unattended operation. The study objective was to establish through performance/cost trade-offs, recommendations for an unattended radar system configuration which provided the highest possible total system functional reliability at reasonable cost without significant compromises to a set of performance goals established by the Air Force at the study outset. The primary emphasis of the study addresses the requirements for a 2 dimensional 60 nautical mile (nmi) radar system for operation on the DEWLINE. A secondary aspect of the study considered the technological demands of a minimal to unattended operation for 3 dimensional 200 nmi air defense radars. The 2D/60 nmi and 3D/200 nmi radars have been designated Type A and Type B* respectively.

This report does not presume to select a specific hardware configuration for a DEWLINE replacement radar. It is very evident that until a mission profile rather than performance goals are established it will not be possible to select a configuration that optimizes cost and performance. This is particularly true in the selection of UHF or L-band as the operating frequency. Operational detection requirements in the presence of multipath will be the primary influence in frequency choice with ECCM and growth to 3D operation secondary issues.

Presented in this report is a family of Type A hardware configurations at both UHF and L-band, based on a common system configuration. Each hardware option has differing operational benefits and related cost performance parameters. It is left to those who determine the ultimate mission requirements to provide the guidance for the ultimate selection of a specific hardware configuration for a replacement radar for the DEWLINE.

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* In accordance with the Statement-of-Work direction the major effort of this study has been directed at the Type A radar. It has not been possible within the time constraints of this study to conclude the rigorous trade-offs required to establish valid conclusions for the Type B system.

SECTION 2

TYPE A DESIGN STUDY

2.1 GENERALIZED DESIGN GUIDELINES

2.1.1 PRIMARY RADAR

The initial task of the study was to identify which of the performance goals should drive a generalized system design. It was determined that the two prime influences were low power consumption and 3 hour visit for repair.

Low power consumption dictated minimum losses particularly at RF. This required all RF amplifying circuits to be mounted in close proximity to the radiating elements of the antenna. Need to eliminate friction, wind resistance and inertia determined an electronic scan in azimuth. Coverage requirements specified 360 degrees in azimuth. This precluded any antenna with limited azimuth scan. However by postulating that the most likely threat is from a high speed target at 100-500 ft altitudes, a 360 degree scanning system is highly desirable to ensure adequate track time (>2 minutes) for high confidence identification of a hostile aircraft. A basic guideline that the antenna must be suitable for mounting on a 100 ft tower to enable contiguous coverage at all elevations for sites spaced at approximately 40 nautical mile intervals imposes the need to constrain the radiating aperture. The low power requirement dictated maximizing the radiating aperture.

The antenna configuration selected for both UHF and L-band is a 44 ft diameter by 7 ft high ring array. The elevation aperture was determined by the number of beams needed to cover 0 to 40° on the assumption the full aperture would be used for transmission and reception. Use of the full aperture on transmission eliminates the need for pulse compression without demanding excessive peak power from transistorized transmitter modules, and simultaneous reception from each beam helps maximize the system detection sensitivity. A 7 ft high elevation aperture provides 6 beams at L-band and 2 at UHF. A larger elevation aperture would give an excessive number of beams to be processed at L-band while 2 beams at UHF provides for a minimum desired amount of system redundancy without excessive RF power demands or hardware complexity.

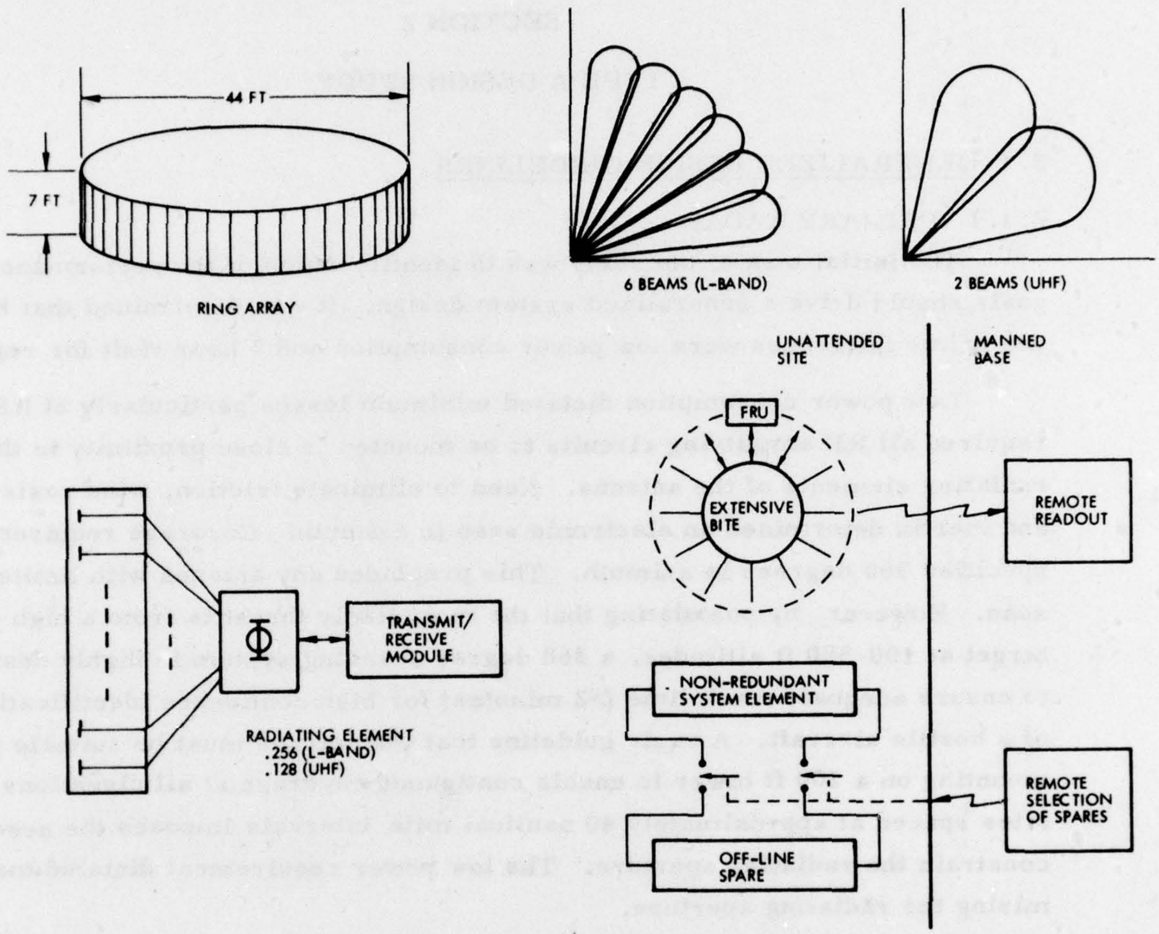

Figure 1. Generalized System Building Blocks

The ring array electronic scan antenna was preferred over other candidates because of the invariant beam shape characteristics over 360^o. The ring array is the nearest electronic equivalent to a mechanically rotated antenna. The diameter was basically determined by element spacing for sidelobe control coupled with judgemental factors on problems of mounting meaningful larger diameters 100 ft in the air. The 44 ft diameter array contains 256 vertical stacks of radiating elements at L-Band and 128 vertical stacks at UHF.

The other prime influence over the generalized system design was determined to be the 3 hour limit placed on a site repair visit. The limit was judged to be reasonable if problems of visiting an unattended site in the Arctic up to 200 miles from a base are considered.

The need was obvious that the failures which occur at unattended site must be known with high confidence before a repair visit is made. This failure must also be known to the field replacement unit (FRU) since simple replacement is the only action realistic at an unattended site in mid-winter.

An extensive status monitoring (BITE) system was needed with remote readout at manned bases. Once the need for extensive BITE was established a tool was available for remote manual switching of spares for failed non-redundant units. This served the dual purpose of minimizing power consumption and eliminating critical self diagnosis/self repair systems. The generalized primary radar system building blocks are shown in Figure 1. It should be noted that reliability issues were not primary considerations in determining the system design. It is a desirable goal of a radar designed for low-cost-of-ownership that it be constructed from a common module replicated many times, while low power consumption dictates a high degree of parallelism in the antenna/transmitter configuration. Both the above features are necessary for a high reliability.

The key feature of radars with >20,000 hour MTBF's is parallelism both at the hardware and system level. Ideally this parallelism in the hardware should be inherent to meeting the basic system performance. In this case redundancy is "for free" and not needed for its own sake. The successful cost effective design of an unattended radar will exploit parallelism in ways that will permit specific amounts of graceful degradation at both hardware and system level without adding redundancy for its own sake.

2.1.2 SIF/IFF

The generalized system design guidelines for the SIF/IFF emerged from philosophies similar to the primary radar. The basic difference is that the SIF/IFF would only issue a challenge for new or dropped tracks. This philosophy was judged to be consistent with the role of an early warning network wherein if the primary radar cannot detect a target SIF/IFF would be of little use.

The need for an electronic azimuth scan follows the same rationale as for the radar, the only options were whether the SIF/IFF antenna should be integrated with or autonomous from the primary radar. This question was resolved in favor of an autonomous system since power budgets for the co-operative SIF/IFF did not require the use of aperture in the same manner as the primary radar. In particular, a single shaped beam covering 0° to 50° was readily acceptable while the only real constraint on azimuth beamwidth was resolution criteria. These considerations lead to a ring array 13 feet in diameter and 15 inches high. The basic azimuth beamwidth from the antenna is approximately 7°, however, by using beam-shaping techniques possible with co-operative systems the effective azimuth resolution is 3.5°. This meets the intent of the goals set by the contract specifications. The same power budget considerations which permitted use of a 13 ft by 1.25 ft ring array also eliminated the need for mounting the RF amplifying circuits at each radiating stack.

It cannot be over emphasized that the co-operative nature of the SIF/IFF detection process ($1/R^2$) and the very low duty cycle of operation proposed for the Type A system make the realization of SIF/IFF unattended operation a very different problem than for the primary radars.

2.2 SYSTEM DESIGN

2.2.1 GENERALIZED SYSTEM BLOCK DIAGRAM

Figure 2 shows the generalized system block diagram of the system. In the case of the IFF system, parameter variables are limited by the co-operative requirements of the system with airborn transponders. The options that are possible for the IFF primarily involve levels of processing capability which again must be determined by mission planners. However, the highly modular microminiaturized nature of the proposed IFF result in minor cost impacts to

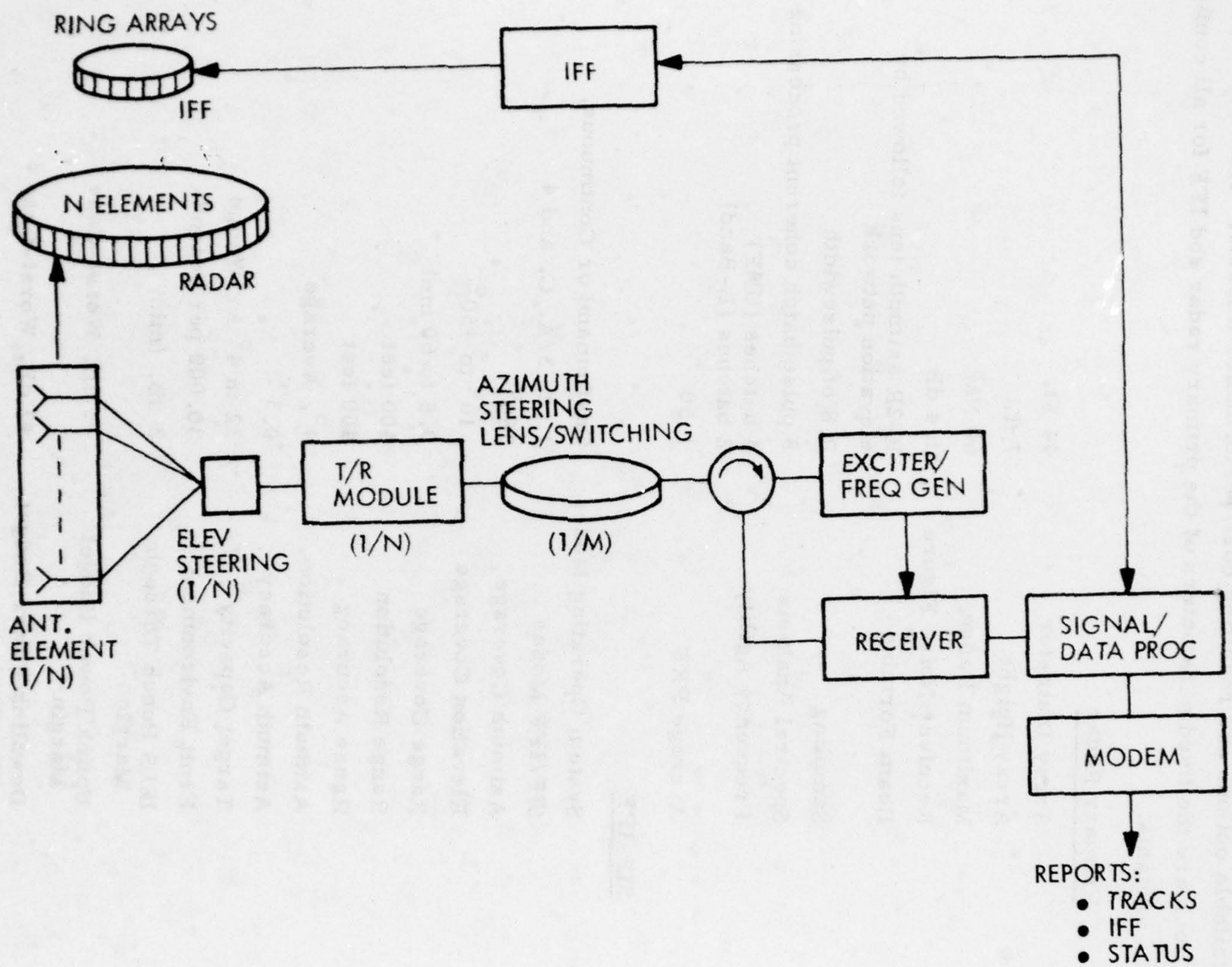

Figure 2. Generalized Type A Radar

the primary radar/IFF combination for any known level of SIF/IFF processing. The primary radar is a considerably different proposition when considering the available options and resulting cost/performance impacts. The following tabulations are the fixed parameters of the primary radar and IFF for all configuration variants.

Primary Radar

Array Diameter	44 Ft.
Array Height	7 ft.
Maximum Range	60 NM
Receiver Noise Figure	1.4 dB
Beam Forming·	R-2R azimuth lens followed by elevation network
Sampling	0.8 of pulsewidth
Spectral Analysis	8 pulse batch coherent processing
Frequency Agility	4 batches (UHF) 2 batches (L-Band)
Average PRF	1150

SIF/IFF

System Operating Modes	On-Demand or Continuous,
SIF/IFF Modes	1, 2, 3/A, C, and 4
Azimuth Coverage	360°
Elevation Coverage	-10° to $+50^{\circ}$
Range Coverage	0.5 to 60 nmi
Range Resolution	400 feet
Range Accuracy	400 feet
Azimuth Resolution	4°, Average
Azimuth Accuracy	0.3°
Target Capacity	32 in 4° AZ Wedge
Fruit Environment	30,000 per second
ISLS Punch Through Margin	3 dB, (min)
Uplink Power Budget Margin	+5 dB, Worst-Case
Downlink Power Budget Margin	+7 dB, Worst-Case

SIF Processing Capability	Full AN/TPX-42A
IFF Target Evaluator Capability	Full AWACS

A physical view of the system is shown in Figure 3. The radar and IFF are housed in a structure atop a tower. The tower height is anticipated to be 100 ft at most sites to meet an assumed requirement that a target at altitudes 100-200 ft must be detectable with 40 nmi separation between radars.

2.2.2 PRIMARY RADAR SYSTEM PARAMETER OPTIONS

The generalized system design guidelines and block diagram permit a number of system configuration options at both UHF and L-Band. Table 1 lists the parameters involved.

Table 1

Scan Structure	Single Frame Split Frame Fence
Elevation Plane Focal Steps	1 or 2 (UHF) 3 or 6 (L-Band)
Transmitter Pulse Length	1.5 or 6 microseconds
Location of solid-state transmitter/receive modules	At radiating stack At quadrant switch
Signal Processing	MTI or MTD

2.2.2.1 Scan Structure

Single Frame

A single frame scan permits all elevation beams to be searched on each azimuth scan. If all elevation beams are simultaneously instrumented, then a good frame time (3.6 sec. for 16 pulses on target), and subsequent track initiation time (14.4 sec) can be achieved. However this type of single frame scan leads to a higher duty cycle (~4% L-Band, 1.4% UHF) with consequent higher power consumption. It also requires more hardware in that a separate receiver and signal processor channel is needed per beam. This amounts to 6 channels at L-Band and 2 at UHF.

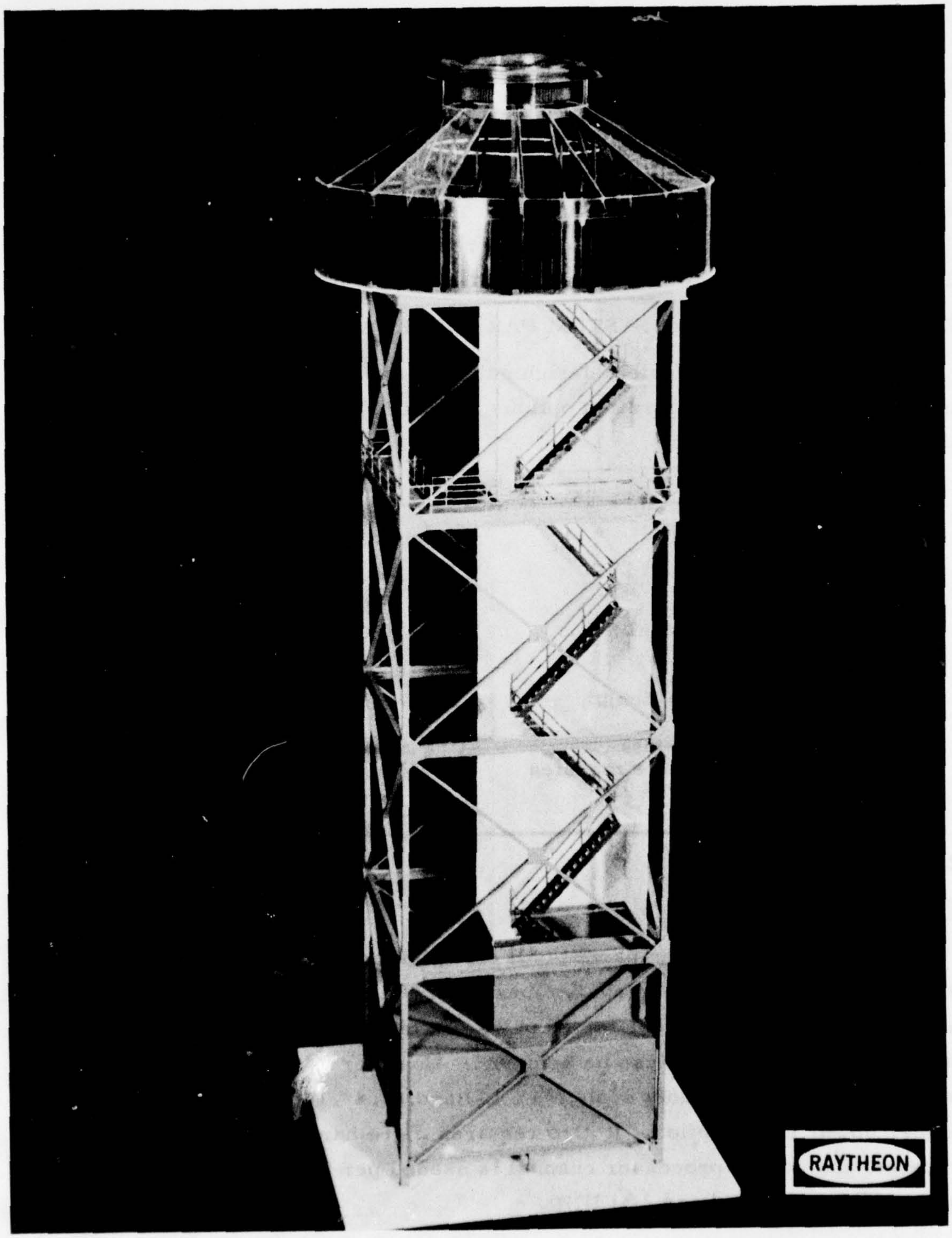

Figure 3. Type A Radar Configuration

An alternative form of single frame scan occurs when only half the number of beams are simultaneously instrumented. The two groups of beams are searched in sequence, but still on the same scan. Half of the receiver and signal processor channels are saved (relative to the fully instrumented single frame scan); however, the frame and track initiation times are also doubled to 7.2 and 28.8 sec, respectively. This frame time can be reduced by using a smaller number of pulses in each beam position, however, the full advantages of either frequency agility or 8 pulse coherent integration must be given up. This is considered an undesirable option.

The single frame system has an intrinsic appeal as it represents the most straightforward and least complex of all scan structures. The radar scan is not required to 'adapt' to the motions of the target. This scan type also possesses the advantage of covering the complete surveillance volume each scan.

It is difficult to satisfy all requirements (low frame time, low power consumption low complexity) simultaneously at L-Band with a single frame scan where six elevation beams are required to fill the search volume for the 30 nmi, 1 square meter cross-section target. These requirements can be met at UHF where only two elevation beams are needed to implement a single scan system with a 4 second frame rate.

Split Frame

The split frame scan was conceived to provide further options to the frame time/hardware complexity dilemma at L-Band. In brief, a split-frame scan searches one half of the elevation volume on each scan and the remaining half on the succeeding scan. If a target is found on a particular beam on a scan, that group of elevation beams is revisited for the next 3 scans on the same azimuth beam. The frame time is 7.2 seconds but the average track initiation time is 16.2 seconds.

The disadvantages of a split-frame are the decreased surveillance update rate and the additional control complexity required in moving beams in response to previous target detections. In addition a penalty of about 0.4 dB is extracted due to higher false alarm threshold requirements.

The use of a split-frame is more attractive at L-Band because of the 6 channels involved. Three receiver/processor channels can be saved while the two beam UHF system will only save one channel at the expense of twice the frame rate.

Fence/Bowl

A minimum energy system can be constructed if the concept of a "tripwire" system is applied literally. Fence/Bowl configuration permits all elevation beams to be searched each scan but only at predetermined range intervals. The advantage is reduction in receiver channels and signal processor memory. Additional data processing logic can be used to maintain update on target in track, however, targets entering the coverage from above the predetermined 1 sq/meter target track initiation fence and tracked targets entering the cone-of-silence would be difficult to pick-up until they penetrate the 1 sq/meter target track initiation fence again. This is likely to prevent two minutes of track time on a high speed target.

Even more than the split-frame, the use of a fence/bowl concept is more suited to L-Band than UHF. A minimum of about 110 nmi of range gates must be searched per azimuth beam position for an L-Band fence/bowl as opposed to 360 nmi for a fully instrumented single frame scan. This can be accomplished with one receiver channel at a frame time of 6.8 seconds or two receivers at a frame rate of 3.6 seconds. The difference at UHF is about 60 nmi in range gates for a fence/bowl as opposed to 120 nmi for a fully instrumented, two beam, configuration.

The primary disadvantage of the fence/bowl is the absence of full volume search. A part from the frame time increase suffered if a single receiver concept is used the lack of a full range 'bowl' on the low beam will prevent the maintenance helicopter from being acquired on departure from the visited site until the 30 nmi fence is reached. This may be undesirable for safety reasons and may dictate that a 2 receiver fence/full range bowl is the minimum system configuration acceptable. In this case the UHF fence/bowl would offer little significant hardware advantage over a full volume single scan configuration at UHF.

2.2.2.2 Elevation Plane Focal Steps

The number of elevation plane focal steps determines the number of parallel azimuth steering networks required. As it is desirable to minimize the number of such networks from cost and power consumption considerations, it was attempted to utilize one network for every pair of beams by focusing between them. This turned out to be feasible; however a substantial focusing loss resulted at high elevation angles particularly at L-band.

The choice between the reduced performance at high elevation angles with the decreased cost and higher performance/higher cost system must again be determined by overall mission detection requirements.

This appears to be more of an issue at L-band as the cost difference between 6 and 3 networks is considerable. At UHF, the choice is between 1 or 2 focal plane network and the overall system cost impact is reduced accordingly.

2.2.2.3 Transmitter Pulse Length

This parameter is one of the most potentially significant differences between UHF and L-band. The maximum pulsewidth to meet range *resolution* requirements is 6 microseconds. This pulsewidth will minimize the signal processor hardware complement. However, on the assumption that range average CFAR is used to suppress extended clutter (weather), a compromise is required between the number of samples in the range window and the CFAR detection loss. Eight range samples are a realistic minimum which in the case of the 6 microsecond pulse, results in a composite threshold for CFAR from radar returns approximately 4 nmi in extent. This threshold generating window is not a good match to many weather cells which can be as small as 1 nmi in extent and therefore can cause considerable loss of detection sensitivity around the weather cell. A 1.5 microsecond transmitted pulse would minimize loss of detection sensitivity but only at the expense of increase in signal processor size, power requirements and failure rates. The pulsewidth is at issue only for L-band since at UHF back scatter from weather is diminished to a point where a 6 microsecond pulse will have minimal impact on loss of detection sensitivity.

Some portions of the DEWLINE are virtual deserts and intense storms rarely occur. Other regions, particularly in Alaska, however, do experience such storms and appropriate CFAR measures must be taken to prevent excessive false reporting.

The issue of pulse length for operation at L-band requires much more detailed evaluation before any final conclusion can be drawn. The tests planned by Lincoln Laboratory on the AN/FPS 20 radar will contribute valuable empirical data in this regard.

2.2.2.4 Location of Transmit/Receive Solid-State Modules (TRSSM)

To minimize R.F. losses the TRSSM's should be mounted at each radiating stack of the antenna. However, for a 44 ft diameter ring array there are 256 stacks at L-band and 128 at UHF. This represents a major acquisition and repair cost because of the number involved. In order to minimize acquisition and repair costs the number of TRSSM's should be reduced to that required to form each instantaneous beam position. In this case 64 radiating stacks need energizing at L-band and 32 at UHF.

This can be achieved by 'walking' 64 or 32 modules around the array controlled by the azimuth steering switches. In this case the modules are located behind the quadrant switch (Q switch). The disadvantage to this technique is that increased power is required from each module because of switching and cable insertion losses. At L-band this loss is about 3 dB and at UHF 1.5 dB. The increased loss at L-band is largely due to the higher cable losses compared to UHF. The increased prime power required to overcome these losses is considered a desirable trade-off in life-cycle-cost.

The peak power required for the L-band module located behind the Q switch is 320 watts for a 1.5 microsecond pulse and 80 watts for a 6 microsecond pulse while the 6 microsecond pulse at UHF requires 200 watts peak. The decision to place the TRSSM either at the antenna or behind the Q switch depends exclusively on the relative cost impact on the system. The effect on cost is not just the acquisition costs of the modules but also includes additional spares and maintenance costs if the module is more complex and thus less reliable. A higher failure rate module would also require a higher level of redundancy in other parts of the system to meet a specified survival time with a stated probability.

2.2.2.5 Signal Processing Techniques

The clutter model provided in the statement of work requires spectral filtering to preserve an acceptable level of false alarms. The general choice lies between MTI and MTD. The distinction is that the MTI has a single bandpass after clutter filtering while the MTD has banks of contiguous filters. The MTI is obviously the simplest mechanism with resultant savings in number of components, failure rate and cost. However, the MTI with non-coherent integration has ~2 dB gain loss over 8 pulses compared to the coherently integrated MTD. This statement assumes that frequency agility is still applied every 8 pulses to reduce fluctuation loss.

It is desirable that coherent integration be used to minimize the system prime power consumption for a given detection sensitivity providing the additional hardware complexity does not produce excessive power consumption, failure rates and cost.

This latter criteria depends on pulsewidth, and number of channels to be processed.

L-band systems have the most demanding processing load due to the 6 beam configuration. Further, the lack of circular polarization from the antenna makes processing of the upper beams highly desirable to provide a degree of subweather visibility. Many of the L-band configurations particularly with 1.5 microsecond pulses will more than swamp the prime power reduction due to a 2 dB sensitivity improvement making MTD processing questionable with presently available technology. However the UHF configuration with 6 microsecond pulses and two channel (beam) processing permit the necessary reductions in MTD hardware complement that make coherent processing highly desirable. The only L-band configuration to permit the same MTD hardware complement is the fence/bowl scan structure.

2.2.3 PRIMARY RADAR SYSTEM HARDWARE OPTIONS

Seventy two (72) system hardware configurations were derived from the parameter options previously discussed. Table 2 summarizes the key characteristics of each option. Although 72 system configurations were identified it can be seen that major subsystem perturbations are few in number. It was therefore decided to select one of the system configurations as a baseline and perform a rigorous engineering design and production cost analysis. The selection of this baseline was basically determined by the validity with which extrapolations could be made to all 72 variants with minimum error. The baseline selected was number 1 of Table 2. It should be stressed that selection of this baseline was not based on any preferences for an ultimate choice of system to satisfy a DEWLINE replacement. The baseline was a study tool to bring focus and visibility to all possible system options.

2.3 COST/PERFORMANCE MODELING

The sequence of events used in the cost/performance trade-off analysis is shown in Figure 4.

The baseline system was first engineered by a rigorous design process. The output of this phase consisted of detailed bills-of-material (BOM) and performance parameters. The design process was iterated with a reliability analysis to ensure a maximum single thread reliability design and minimum amount of additional hardware redundancy required for reliability purposes. The radar design that evolved from the original driving influence of low power consumption resulted in a highly parallel hardware configuration. As a result, it became apparent that reliability considerations alone had very little impact on the basic single thread design of the hardware. As can be seen from Table 3 a minimal amount of standby spares have been added to the baseline to meet 20,000 hours MTBF (90% probability of survival for 3 months). If the graceful degradation characteristics of the baseline configurations are disregarded and every part failure considered a system failure the radar would have a 272 hour MTBF. It is therefore an interesting premise that a radar capable of >20,000 hours MTBF must have a >50:1 ratio between the MTBF (system) and MTBF (event).

Table 2. Type A Alternative System Configurations

No.	Freq.	Scan Type	No. Beams	No. Lenses	No. Rcvrs	ΔT Trans. (μs)	ΔT Pulse (μs)	TRSSM Loc	Det Rule	No. TRSSM	Pwr/Mod (w)	R.G./CPI	Frame Time (sec)	T.I. Time (sec)	Comment
1.	L	Split	6	3	3	18	6	ANT	3/4	256	40	450	$7.2^{(1)}$	$16.2^{(1)}$	**Baseline**
2.	L	Split	6	6	3	18	6	ANT	3/4	256	40	450	$7.2^{(1)}$	$16.2^{(1)}$	Imp. high el. coverage
3.	L	Split	6	3	3	4.5	1.5	ANT	3/4	256	160	1800	$7.2^{(1)}$	$16.2^{(1)}$	
4.	L	Split	6	6	3	4.5	1.5	ANT	3/4	256	160	1800	$7.2^{(1)}$	$16.2^{(1)}$	Imp. high el. coverage
5.	L	Split	6	3	3	18	6	Q.SW.	3/4	64	80	450	$7.2^{(1)}$	$16.2^{(1)}$	Reduced control comp.
6.	L	Split	6	6	3	18	6	Q.SW.	3/4	64	80	450	$7.2^{(1)}$	$16.2^{(1)}$	Imp high el. coverage
7.	L	Split	6	3	3	4.5	1.5	Q.SW.	3/4	64	320	1800	$7.2^{(1)}$	$16.2^{(1)}$	
8.	L	Split	6	6	3	4.5	1.5	Q.SW.	3/4	64	320	1800	$7.2^{(1)}$	$16.2^{(1)}$	
9.	L	Single	6	6	6	$36^{(2)}$	6	ANT	3/4	256	40	900	3.6	14.4	Inc. rad. pwr. & comp.
10.	L	Single	6	6	3	18	6	ANT	3/4	256	40	450	$7.2^{(1)}$	$28.8^{(1)}$	Excess. frame time
11.	L	Single	6	3	3	18	6	ANT	3/4	256	40	450	$7.2^{(1)}$	$28.8^{(1)}$	Above + red. el. cov.
12.	L	Single	3	3	3	18	6	ANT	3/4	256	40	450	$7.2^{(1)}$	14.4	Loss of hi. el. coverage
13.	L	Single	6	6	6	9	1.5	ANT	3/4	256	160	3600	3.6	14.4	Inc. rad pwr & comp.
14.	L	Single	6	6	3	4.5	1.5	ANT	3/4	256	160	1800	$7.2^{(1)}$	$28.8^{(1)}$	
15.	L	Single	6	3	3	4.5	1.5	ANT	3/4	256	160	1800	$7.2^{(1)}$	$28.8^{(1)}$	Reduced hi. el. coverage
16.	L	Single	3	3	3	4.5	1.5	ANT	3/4	256	160	1800	$7.2^{(1)}$	14.4	Loss of hi. el. coverage
17-20		Same as 9 - 12						Q.SW.	3/4	64	80	Same as 9 - 12			Mod. pos. trade-off
21-24		Same as 13 - 16						Q.SW.	3/4	64	320	Same as 13 - 16			
25	L	Fence	6	6	2	36	6	ANT	3/4	256	40	280	3.4	13.7	10 nm "thick" fence
26	L	Fence	6	6	1	36	6	ANT	2/3	256	40	280	6.8	20.5	Won't handle **max** speed tgt.
27	L	Fence	6	3	2	36	6	ANT	3/4	256	40	280	3.4	13.7	Reduced hi. el. coverage
28	L	Fence	6	3	1	36	6	ANT	2/3	256	40	280	6.8	20.5	Reduced hi. el. coverage

Notes: (1) Track initiation time and average frame time can be reduced by one-fourth if top 3 beams instrumented only to 30 NM with *corresponding* "hole" in coverage.

(2) Transmitter radiation time in one effective pulse repetition interval (one-eighth of CPI).

Table 2. Type A Alternative System Configurations (Cont)

No.	Freq.	Scan Type	No. Beams	No. Lenses	No. Rcvrs	ΔT Trans. (μs)	ΔT Pulse (μs)	TRSSM Loc	Det Rule	No. TRSSM	Pwr/Mod (w)	R.G./CPI	Frame Time (sec)	T.I. Time (sec)	Comment
29-32		Same as 25 - 28				9	1.5		Same		160		Same		Pulsewidth trade
33-36		Same as 25 - 28						Q.SW.	Same	64	80		Same		Mod. pos. trade
37-40		Same as 25 - 28				9	1.5	Q.SW.	Same		320		Same		Pw + Mod. pos. trade
41	UHF	Single	2	2	2	12	6	ANT	3/4	128	150	300	3.6	14.4	
42	UHF	Single	2	2	1	6	6	ANT	3/4	128	150	150	7.2$^{(1)}$	28.8$^{(1)}$	Excessive frame time
43	UHF	Single	2	1	1	6	6	ANT	3/4	128	150	150	7.2$^{(1)}$	28.8$^{(1)}$	Above + red. el. cov.
44	UHF	Single	1	1	1	6	6	ANT	3/4	128	150	150	3.6$^{(1)}$	14.4$^{(1)}$	Loss of elev. cov.
45	UHF	Single	2	2	2	3	1.5	ANT	3/4	128	600	1200	3.6	14.4	
46	UHF	Single	2	2	1	1.5	1.5	ANT	3/4	128	600	600	7.2$^{(1)}$	28.8$^{(1)}$	
47	UHF	Single	2	1	1	1.5	1.5	ANT	3/4	128	600	600	7.2$^{(1)}$	28.8$^{(1)}$	
48	UHF	Single	1	1	1	1.5	1.5	ANT	3/4	128	600	600	3.6$^{(1)}$	14.4$^{(1)}$	
49-52		Same as 41 - 44						Q.SW.	Same	32	200		Same		
53-56		Same as 45 - 48						Q.SW.	Same	32	800		Same		
57	UHF	Split	2	2	1	6	6	ANT	3/4	128	150	150	7.2	16.2	
58	UHF	Split	2	1	1	6	6	ANT	3/4	128	150	150	7.2	16.2	Red. in el. coverage
59-60		Same as 57 - 58				1.5	1.5	ANT	3/4	128	600	600	7.2	16.2	Pulsewidth trade
61-62		Same as 57 - 58						Q.SW.	3/4	32	200	150	7.2	16.2	Mod. Pos trade
63-64		Same as 57 - 58				1.5	1.5	Q.SW.	3/4	32	800	600	7.2	16.2	Pw/Mod pos. trade
65	UHF	Fence	2	2	1	12	6	ANT	3/4	128	150	150	3.6	14.4	15 nm "thick" fence
66	UHF	Fence	2	1	1	12	6	ANT	3/4	128	150	150	3.6	14.4	Red. hi. el. cov.
67-68		Same as 65 - 66				3	1.5		Same		600	600	3.6	14.4	Pulsewidth trade
69-70		Same as 65 - 66				12	6	Q.SW.	3/4	32	200	150	3.6	14.4	Mod. pos. trade
71-72		Same as 65 - 66				3	1.5	Q.SW.	3/4	32	800	600	3.6	14.4	Pw/pos. trade

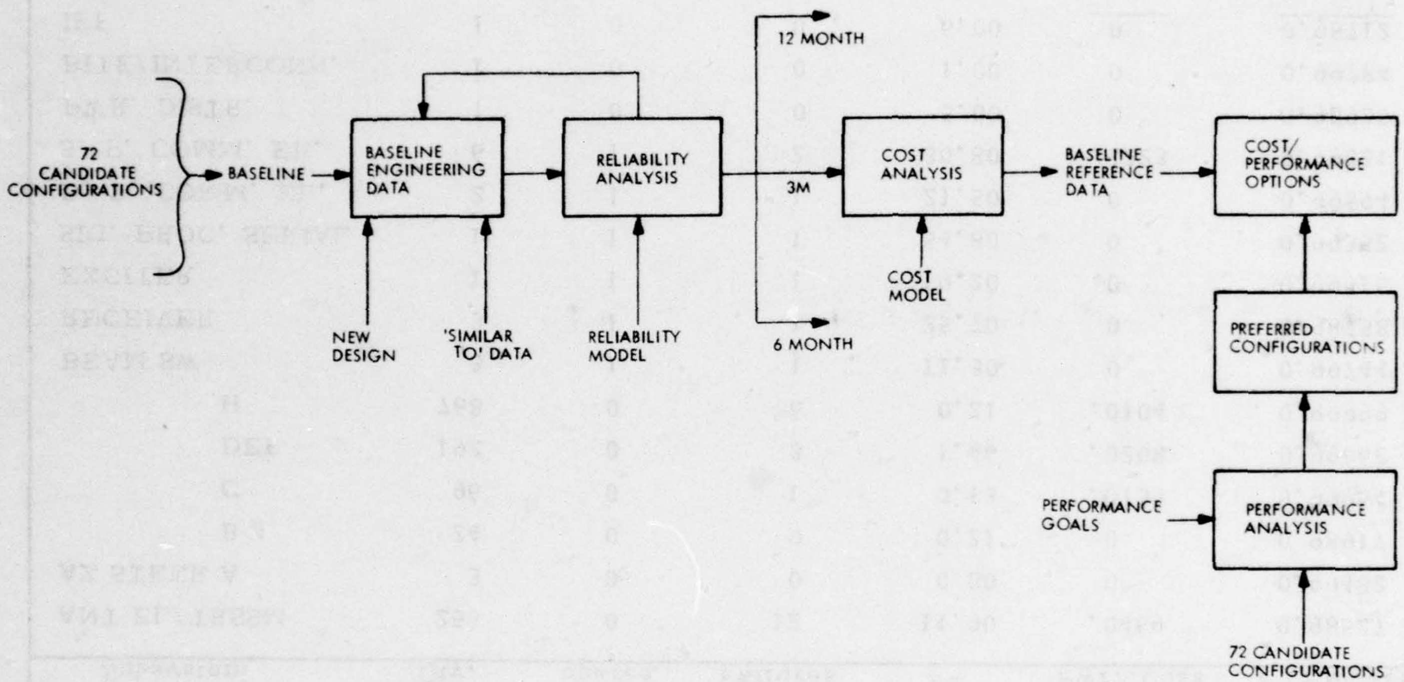

Figure 4. Cost/Performance Modeling Sequence

Table 3. Baseline Configuration Reliability Apportionment (90% PS/3 Months)

Subsystem	On-Line Qty.	Stdby. Spares	Allowable Failures	Element λ*	Allowable Pwr. Loss	P (3 mos.)
ANT EL/TRSSM	256	0	12	11.90	.0469	0.98527
AZ STEER A	3	0	0	0.80	0	0.99482
B	24	0	0	0.21	0	0.98917
C	96	0	1	0.13	.0139	0.99964
DEF	192	0	3	1.46	.0208	0.99662
H	768	0	6	0.21	.0104	0.99999
BEAM SW	3	1	1	11.30	0	0.99744
RECEIVER	3	1	1	25.70	0	0.98758
EXCITER	1	1	1	19.20	0	0.99916
SIG. PROC. SERIAL	1	1	1	54.80	0	0.99352
D. P. COMM. EL.	2	1	1	21.50	0	0.99594
S. P. COMM. EL.	6	1	2	30.80	.2223	0.99331
PWR. DISTR.	1	0	0	5.00	0	0.98925
BITE/INTERCONN.	1	0	0	1.00	0	0.99784
IFF	1	0	0	6.00	0	0.98712
					.3143	0.91054

*Failure rates in units of failures per 10^6 hours.

The cost analysis was keyed to an assumed sequence of events for the program. Figure 5 illustrates the phases considered realistic to meeting the program demands and the level of pricing commitment at each phase.

Also shown are the time relationships between the four phases for the three design times (3, 6, and 12 months). A fixed development and contractor factory test time has been assumed for all design times (3 years). The number of prototypes and the duration of Arctic testing varies with the design time. These parameters (number of prototypes, Arctic test time) have been chosen to give an essentially equal confidence level in system reliability for the three times. The confidence achieved with this level of testing is about 50 percent.

Figure 6 is a plot of test duration vs statistical confidence in the test results for a 20,000 hour MTBF radar. It can be seen that a single scorable system failure will have dramatic impact in either confidence level or time-to-decision. The issue of what constitutes a system failure will have greatest overall impact on the program of any unresolved risk area. One of the critical tasks to be accomplished during the conceptual phase is to establish the reliability test plan including detailed agreement with the Air Force as to test conditions, failure modes and ground rules.

A life-cycle-cost model was developed for the overall program and the preferred radar configurations resulting from a detailed performance analysis subjected to a rigorous cost analysis. Table 4 is a summary of the performance cost trade-offs for the preferred system configurations.

2.4 CONCLUSIONS

A family of unattended radars has been studied for application on the DEWLINE. These radars were designed for operation at both UHF and L-band. There is no one configuration that stands out as a recommended solution for the DEWLINE application. This is particularly true in the case of small targets (1 sq meter) at low altitudes (<500 ft). Selection of the operating frequency for the DEWLINE will only be possible when a better definition of cumulative detection including duration and number of continuous track periods for specific targets are established. The latter issue will also determine the need for 360 degree azimuth coverage.

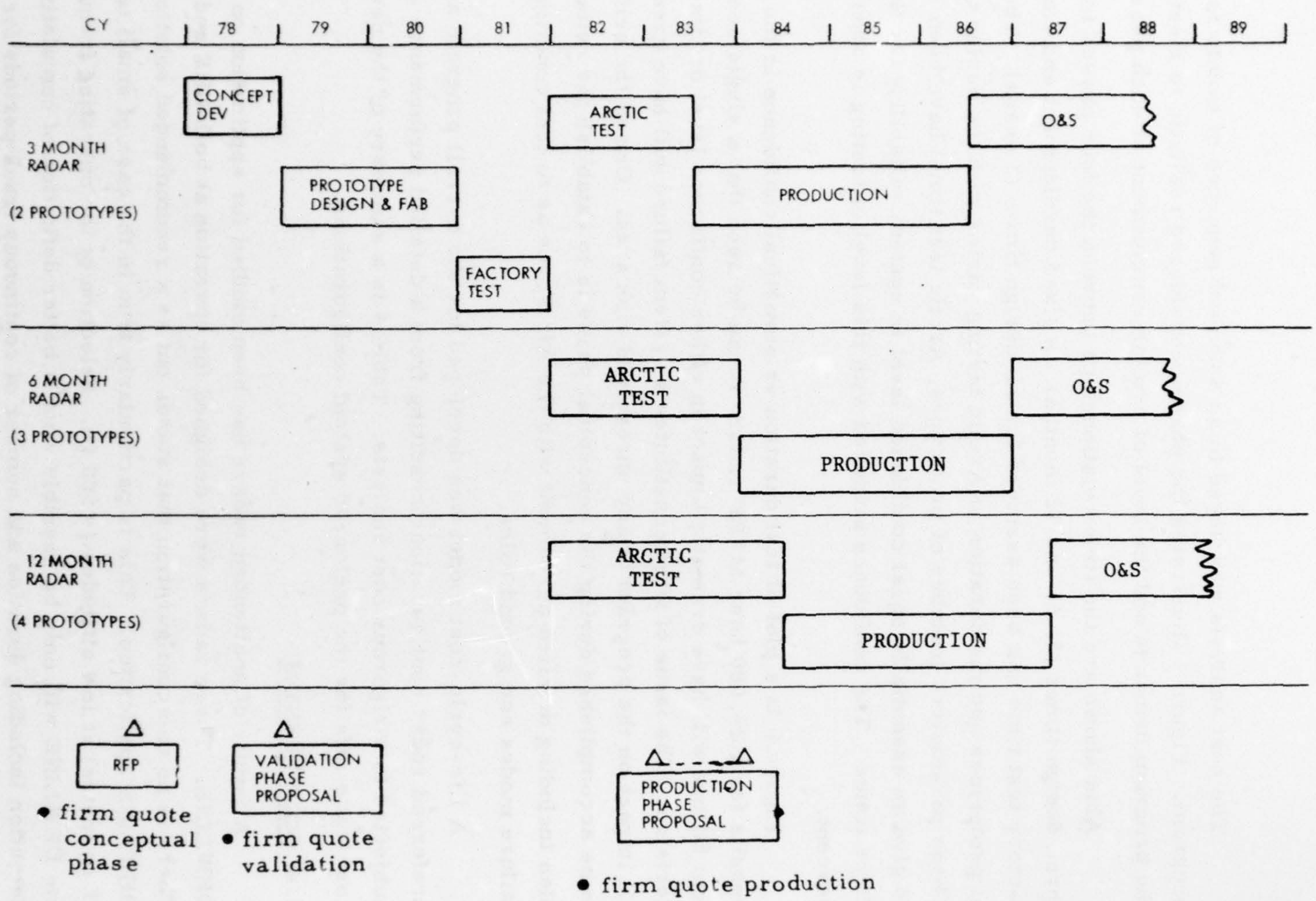

Figure 5. Type A Program Phasing

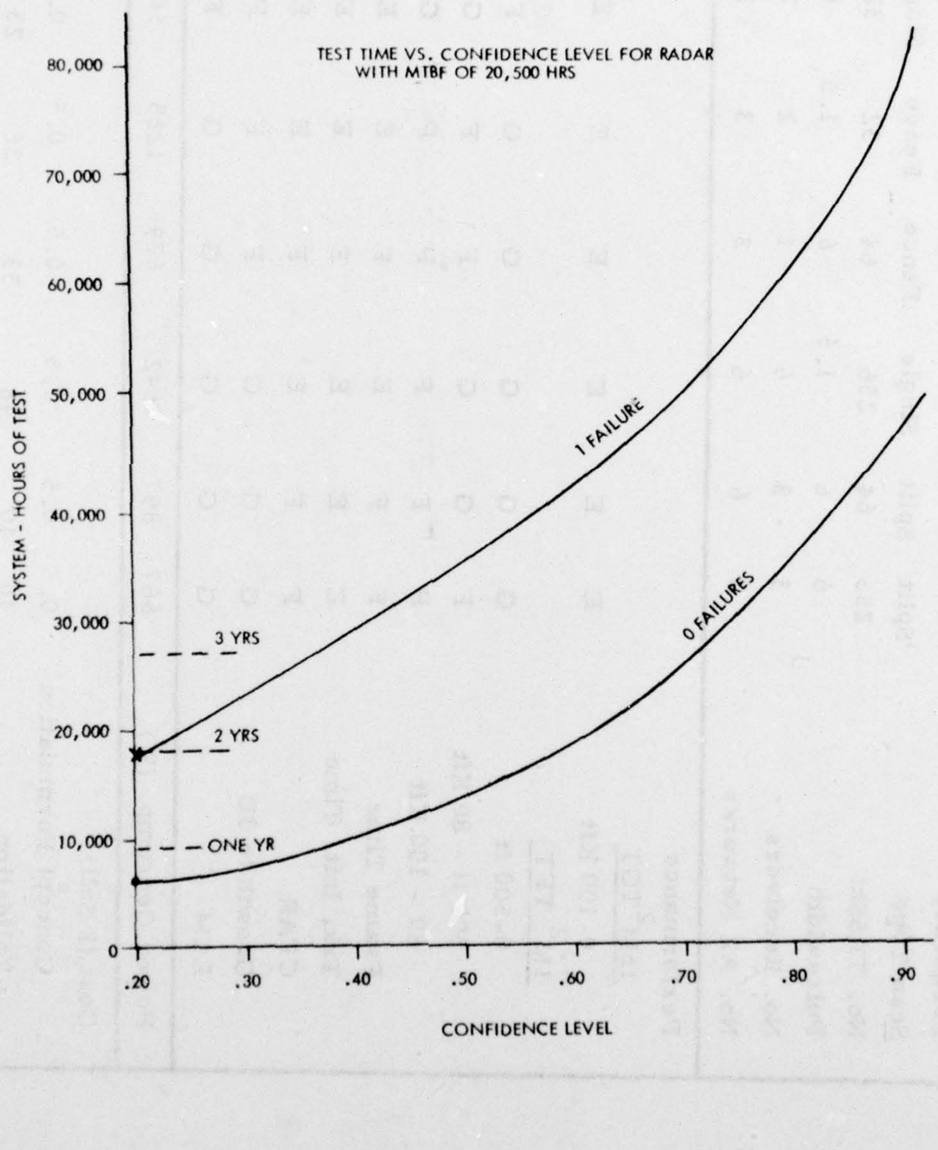

Figure 6. Reliability Test Time vs Confidence Level (90% PS/3 Months)

Table 4. Configuration Trade-Offs

Configuration	1	6	13	36	39	49	62	49 (A/J)
Frequency	L	L	L	L	L	UHF	UHF	UHF
Scan Type	Split	Split	Single	Fence	Fence	Single	Split	Single
No. TRSSM	256	64	256	64	32	32	32	32
Pulsewidth	6	6	1.5	6	1.5	6	6	6
No. Receivers	3	3	6	1	2	2	1	2
No. AZ Networks	3	6	6	3	3	2	2	2
Performance								
$16M^2$TGT								
0-100 Kft	E	E	E	E	E	E	E	E
$1M^2$ TFT								
0-500 ft	G	G	G	G	G	F	F	F
500 ft - 80 Kft	F	G	G	F	F	G	G	G
80 - 100 Kft	P	F	F	P	P	G	G	G
Frame Time	F	F	E	F	E	E	F	E
Trk. Init. Time	E	E	E	F	E	E	E	E
CFAR	F	F	E	F	E	E	E	E
Growth to 3D	G	G	G	F	F	P	P	P
ECM	G	G	G	G	G	F	F	G
Power Consump. (W)	667	897	1642	679	1263	569	372	606
Cost ($ Sell)								
Concept Formulation	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Validation	40	40	48	33	36	23	21	27
Investment	223	219	273	174	190	128	115	155
O & S	52	26	64	24	38	20	17	27
Total	316	286	386	231	264	172	154	210

P = Poor F = Fair (below goals) G = Good (meets goals) E = Excellent (exceeds goals)
A/J = anti-jam

The UHF variants of the radar family are less expensive than the nearest L-band equivalent. For this reason UHF is very attractive. However UHF has relatively few ECCM features and virtually no growth potential to 3D operation.

A design goal of 500 watts prime power for the radar/operation was established at the study outset. This requirement became the driving influence in the system design. In retrospect this prime power constraint was a good influence in that the resulting radar configuration contained the features needed for very high reliability, such as parallelism, and minimum parts count. Very low power is considered fundamental to the ultimate realization of unattended radar systems: An unattended radar cannot function without an unattended power source. The lower the power demanded, the more viable the realization of a highly reliable power source. Minimum power dissipation in the radar is consistent with maximum reliability. The more internal heat generated by a component the higher the failure rate. The actual goal of 500 watts may be achievable at UHF but not L-band. It is considered more realistic to increase the available prime for any operational system to at least 1000 watts. If L-band configurations with 1.5 microsecond transmit pulses are ultimately required to satisfy mission requirements, 1500-2000 watts of prime power will be needed.

The IFF system for use with unattended radars is also shown to be readily attainable with proven techniques. Because of a proposed mode of on-demand IFF operation for Type A radars which requires IFF interrogations only for new or dropped tracks and the predicted low aircraft populations at DEWLINE sites, a 30:1 improvement in equipment failure rates over continuous operation has been conservatively estimated, greatly simplifying IFF reliability and power consumption demands.

The nature of the IFF mission, the modularity and small physical size of the equipment, coupled with a proposed near-dormancy operational mode, make a highly reliable IFF system a much simpler proposition than the primary radar.

Technology is potentially available to build radars with MTBF's an order of magnitude greater than that exhibited by present radar systems. Whether radars with >20,000 hours MTBF are practical or even necessary depends on the commitments required of the manufacture for his emplaced equipment and

a detailed understanding with the customer as to what constitutes a failure. A sensitive balance is required between inherent hardware complement of the radar particularly for redundancy purposes and the frequency with which repair visits are required. More redundancy will permit extended periods of unattended operation but will also require higher acquisition and repair costs. The cost-effective realization of an operational system of unattended radars particularly in a network of radars with overlapping coverage will depend to a large extent on the data availability required and the downtime permissable at any radar.

The greatest unknown, and therefore risk identified in the study is the acceptability of the reliability model assumptions. These assumptions in turn impact the redundancy requirements and hence the cost and viability of radars for extended periods of unattended operation.